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APPLICATION OF REMOTE SENSOR DATA

TO

GEOLOGIC ANALYSIS OF THE BONANZA TEST SITE

COLORADO

SEMIANNUAL PROGRESS REPORT

1 October 1974 - 31 March 1975

Remote Sensing Report 75-2

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April 1975



**REMOTE SENSING PROJECTS**

DEPARTMENT OF GEOLOGY

COLORADO SCHOOL OF MINES • GOLDEN, COLORADO

APPLICATION OF REMOTE SENSOR DATA  
TO  
GEOLOGIC ANALYSIS OF THE BONANZA TEST SITE  
COLORADO

SEMIANNUAL PROGRESS REPORT

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APPLICATION OF REMOTE SENSOR DATA  
TO  
GEOLOGIC ANALYSIS OF THE BONANZA TEST SITE  
COLORADO

Semiannual Progress Report  
1 October 1974 - 31 March 1975

INTRODUCTION

This report summarizes the research activities of the Colorado School of Mines faculty and students for the period 1 October 1974 - 31 March 1975. During this period, Professor Keenan Lee, Research Associate D.L. Sawatzky, and graduate students J.C. Fisher, David Huntley, and Loren Lasky carried out research under the project.

## REMOTE SENSING APPLIED TO URANIUM EXPLORATION

Areas of uranium mineralization often are sites of anomalous surface features that may be sensed remotely and utilized in an exploration program. These surface features often are manifestations of actual mineralization, but more commonly are characteristics of well-studied uranium depositional models. An occurrence of one, or even several, of these characteristics does not guarantee an economic uranium deposit, but in general provides excellent prospecting targets and allows the explorationist to discard large, less prospective areas.

Selected examples of these features commonly associated with the various types of uranium deposits and recommendations for various sensor applications are presented.

### I. Epigenetic Uranium Ore Roll Type (Wyoming and New Mexico deposits)

A. Fluvial or lacustrine sandstone units such as braided channel deposits or alluvial fan deposits. Poorly cemented, easily-weathered, light colored, detrital rock units, often displaying radical thickness changes and channeling characteristics along outcrop exposures.

These features are probably best sensed by low-altitude color and black and white photography. Great detail is needed to sense subtly expressed lithofacies variations.

B. Reducing/oxidizing geochemical roll fronts seen in the outcrop as red, green, or bleached gray alteration boundaries.

Color photography is the recommended sensor as it provides color definition that can help discriminate true geochemical fronts from other tonal or lithologic banding.

C. Nearby exposures of well-weathered granitic rocks or ash-fall volcanic rocks. These igneous rock types are usually theorized as being the sources of the uranium.

Small-scale, synoptic coverage satellite products are probably the best sensors to use to identify typical igneous plutonic or volcanic features. Skylab S190B terrain mapping camera photography is ideal for this task where it is available.

## II. Precambrian Basal Conglomerate Type (Canadian and South African deposits)

A. Coarse-grained, continental detrital units, often associated with erosional channeling or cut-and-fill scouring structures in underlying units.

High altitude black and white photography should provide an excellent mapping medium for these features where they are adequately displayed in outcrops.

B. Greenish, pyritically reduced iron color, lack of significant hematitic or limonitic color.

Medium- to low-altitude color photography provides the best information on these color features.



C. Absence of carbonate rock units in the same stratigraphic sequence or lower in the section. May indicate the onset of oxidizing atmosphere before deposition, which does not permit the deposition of placer uranite and brannerite grains.

Medium-scale black and white photography provides an excellent product to discriminate karst weathering features or rectilinear drainage patterns often typical of carbonate rock units.

### III. Vein-Type Uranium Deposits (Colorado Front Range and Beaverlodge, Canada)

A. Pervasive, possibly deep-rooted fault and fracture systems. Often seen as alignments of stream segments, slope breaks, ridge tops or saddles, ridge spurs and other features. Fault systems probably control the vein deposits in many cases.

Low sun-angle photography (LSAP) or side-looking airborne radar (SLAR) sensor products enhance faults and fracture systems that are topographically expressed. Thermal infrared scanner imagery may also provide excellent information on fault zones that control water movement. Color infrared photography is useful where vegetative vigor anomalies are fault controlled. In general, though, high-altitude photography, color or black and white, provides the greatest information with the least expense.

B. An almost universal occurrence of limonitic or hematitic alteration color anomalies.

Low-altitude color photography provides the best information on these features.

C. Possible bright green or blue copper mineralization associated with vein uranium mineralization.

Low altitude color photography is also the most obvious sensor choice for this features.

IV. Pipe-structure or Diatreme Deposits (Arizona and Black Hills, South Dakota)

A. Circular, possibly cryptovolcanic or solution collapse features. Often accompanied by annular fracturing or drainage patterns.

The best sensor is probably high-altitude black and white or color photography. Color infrared photography is often useful where vegetation grows preferentially in the subtly-expressed arcuate fault zones.

V. Evaporitic Uranium Deposits (Various Australian and Asian deposits)

A. Extensive playa lake or caliche deposits, white calcium carbonate coatings and associated centripetal drainage patterns.

High-altitude or satellite photography is quite useful in exploring for these features.

B. Colorful uranium mineral deposits often appearing as bright yellow, green or orange crusts or stains.

Low-altitude color photography is possibly the only sensor adequate to provide information on these very subtle uranium indicators.

The uranium deposit surface features mentioned above represent only a few of the most obvious characteristics that are possible exploration aids that can be remotely sensed. Many other types of deposits have produced economic uranium and have their own distinctive surface features that can be remote sensed.

With a thorough knowledge of these surface features, the various uranium depositional mechanisms, and a knowledge of the remote sensors, a successful exploration program for uranium ore should be possible. No explorationist should expect to discover drillable targets, but areas of high mineralization potential could be outlined in the initial stages of an exploration program.

#### Plans for Next Reporting Period

The research described above will be concluded during the next reporting period. A final report should be published during this period.

## HYDROGEOLOGY - MOSQUITO RANGE

The Mosquito Range hydrogeology study is in the final stages of report writing. The study area has been described in previous remote sensing reports, and is the headwaters of the Middle Fork, South Platte River. The river is the drainage for the east slope of the Mosquito Range above Fairplay, Colorado. The study is evaluating the usefulness of color and color infrared photography for hydrogeologic studies in a mountainous region. The study results are divided into three sections: water chemistry, ground water movement, and ground water occurrence.

Photography was not used in the water chemistry study, except for locating potential pollution sources such as mine dumps and tailings ponds. These sites were noted on the air photos for future field checks.

Generalized information about the ground water movement was obtained from the air photos by analyzing fracture patterns in crystalline rocks, attitudes of dipping sedimentary beds, topography, and phreatophytic plant associations.

Photography was the most useful for studying ground water occurrence. A surficial geologic map was prepared from low-altitude color photography. Surficial units and heavy vegetation, however, made a study of the bedrock geology difficult. Fracture analysis of the crystalline rocks delineated potential aquifer areas. Areas of end moraines

were separated from the general term till, and represent potential aquifers. No evidence was found to differentiate fluvial deposits within the till from the till itself. Phreatophytes were used as indicators of very shallow ground water.

## HYDROGEOLOGY - SAN LUIS VALLEY

Research during this reporting period consisted of photo-interpretation of remote sensing images covering the volcanic terrain west of San Luis Valley and construction of apparatus to measure thermal diffusivity and thermal conductivity of soil samples.

### Photo-interpretation

Lithologic units present in the La Garita Hills region (Fig. 1) include andesitic flows and breccias, ash-flow tuffs with varying degrees of welding, air-fall and water-laid tuffs and laharc mudflows and breccias. Before mapping of the units was begun, a preliminary evaluation of relative permeabilities was made. Brief field observations suggested that the greatest source of permeability is the extensive primary fracturing of volcanic units. Measurements of intergranular permeability of small core specimens from the test site verify this interpretation for welded and moderately welded ash-flow tuffs. Of ten specimens tested, eight had permeabilities of less than 0.75 millidarcys. Of the two remaining specimens, one result is suspect because of inadequate seal around the sample, and the other indicated a relatively high permeability of 52.4 millidarcys in a very vesicular, welded ash-flow tuff. This compares well with

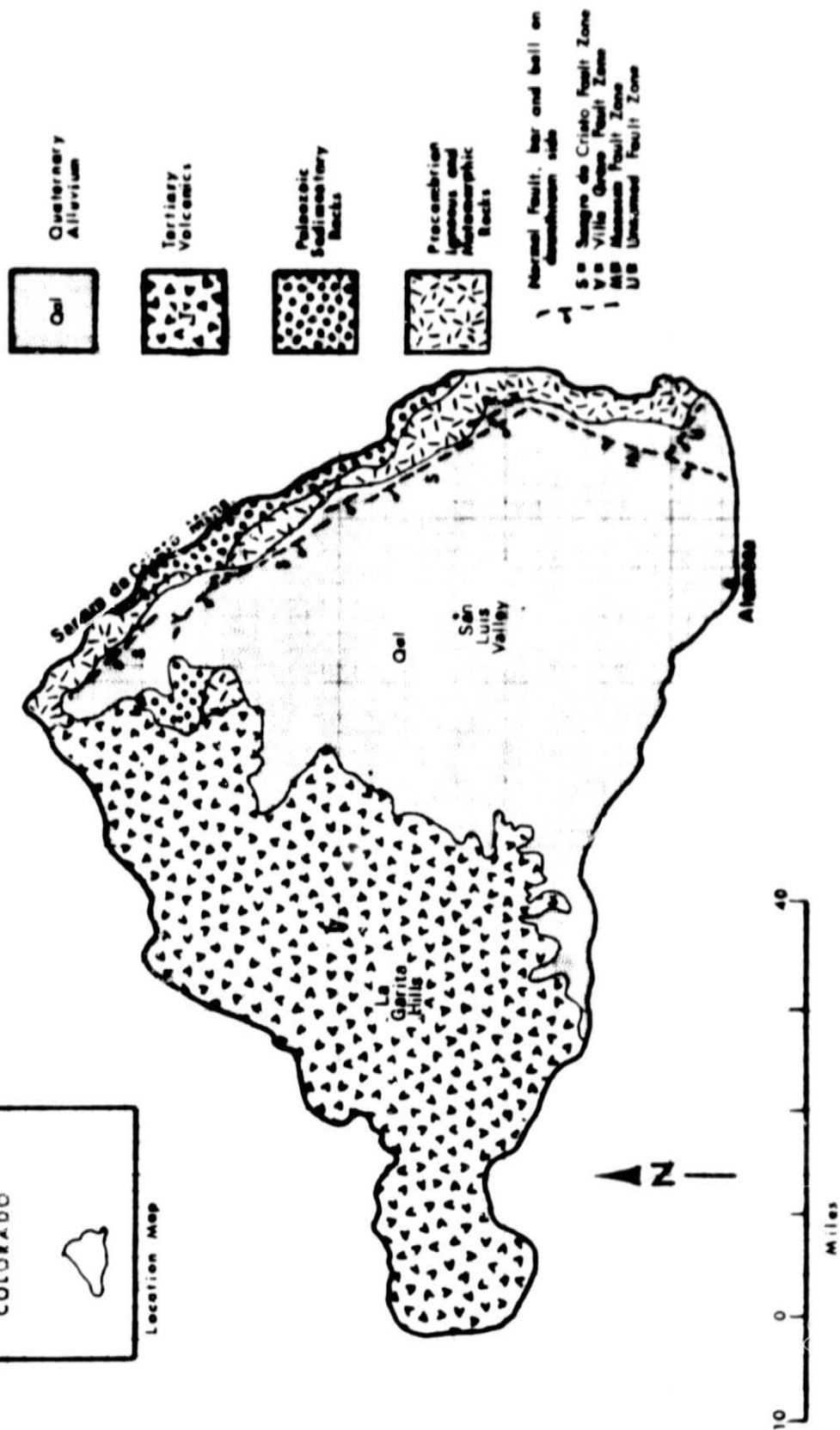
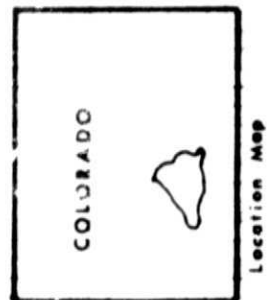


Figure 1. Generalized geologic map of San Luis Valley test site.

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results presented by Winograd (1971) for ash-flow tuffs at the Nevada Test Site. Intergranular permeabilities in this study ranged from 0.01 millidarcys in densely welded tuffs to 109 millidarcys in unwelded tuff. In contrast, coefficients of permeability due to fracturing at the Nevada Test Site were determined to vary between 7 and 38 darcys, three orders of magnitude greater than intergranular permeability values. Permeability computations by this author, based on spring discharges from the fractured and welded portions of ash-flow tuffs in the La Garita Hills, indicate permeabilities are on the order of 50 darcys. In comparison, permeability values for the confined aquifer of the San Luis Valley vary between 4 and 44 darcys (Emery & others, 1973).

It has been tentatively assumed that intergranular permeability is low in unwelded ash-flow tuffs, air-fall tuffs, water-laid tuffs, and laharic deposits. This assumption will be checked during the field season with infiltration tests designed to give order-of-magnitude values of permeability.

This analysis indicates that the significant aquifers of this area include only fractured ash-flow tuffs and andesitic or basaltic flows and possibly any regionally extensive fluvial deposits from times of volcanic quiescence. It should be noted that the fracture permeability in this area is dominantly primary, so permeability will not be a direct function of depth, as it is in the Sangre de Cristo Mountains.

Aquicludes or aquitards include unwelded ash-flow tuffs, air-fall and water-laid tuffs, laharic deposits, and intrusive centers, dikes, and sills.



Hydrostratigraphic units were mapped on the basis of the above analysis using small-scale (1:110,000) color and color-infrared photography, medium-scale (1:55,000) color-infrared photography, and, where it was available, large-scale (1:18,000) color-infrared photography. Although a complete evaluation of the relative usefulness of this interpretation must wait for field work during the next reporting period, some preliminary observations, based on ease of interpretation and confidence in the resulting interpretation, can be made.

1) Frequent points of control, or areas where the stratigraphic units are known and can be identified on the photography, are a necessity in volcanic terrain. Because of the control pre-existing topography exerts on the depositional patterns of volcanic units, correlation between units over large, uncontrolled areas is tenuous.

2) Discrimination between ash-flow tuffs based on color, drainage patterns, or outcrop resistance is often impossible. In this study area, only one ash-flow tuff has a distinctive appearance on the photography. Fortunately, this unit is an important marker bed and can be used to delineate much of the geology in the region. It must be noted, however, that discrimination between several ash-flow units is difficult even in the field, and the same ash-flow tuff that is important on the photography is important as a field marker bed because of its distinctive mineralogy.

3) Discrimination between andesite flows and devitrified portions of ash-flow tuffs is often difficult, particularly where soils are well-developed.

4) Discrimination between air-fall tuffs, water-laid tuffs, and laharc deposits is not possible on photography. Discrimination between the above deposits and andesitic flows and ash-flow tuffs is possible in most areas because of the high reflectance, low erosional profile, and dendritic drainage pattern of the air-fall, water-laid, and laharc tuffs.

5) Springs and areas of shallow ground water are apparent in regions with sparse coniferous vegetation. In areas of dense coniferous vegetation, springs with discharges as great as 1.5 cfs may not be visible.

6) Remote sensing interpretation appears to be most successful in sparsely vegetated areas with frequent control points and least successful in thickly vegetated areas with infrequent control points.

7) Photo-interpretation in the field, where control points can be established and complex areas can be visited, may be a more efficient use of photography, though large areas of relatively uncomplicated, sparsely vegetated terrain were mapped with a fair degree of confidence.

#### Thermal Experiments

In conjunction with studies to determine the effect of ground water depth, soil moisture, and soil type on radiometric

temperatures, an apparatus was designed to measure thermal diffusivity of wet and dry soils. The apparatus consists of a simple planar heat source (a hotplate) and a sample box, insulated on five sides and heat-conductive on one end. Soil temperature at known distances from the heat source is measured at successive time intervals. The one-dimensional transient heat flow equation is;

$$\frac{d^2T}{dx^2} = \frac{1}{\alpha} \frac{dT}{dt}$$

where T = temperature

x = distance

$\alpha$  = thermal diffusivity

t = time

If temperature is measured at points  $x_1$ ,  $x_2$ , and  $x_3$  from the heat source, each point separated by distance  $\Delta x$ , then  $\frac{d^2T}{dx^2} = \frac{(T_1 - T_2) - (T_2 - T_3)}{(\Delta x)^2}$ . The quantity  $\frac{dT}{dt}$  can be measured at point  $x_2$ , and thermal diffusivity is computed by simple division. Thermal conductivity can be computed using measured values of thermal diffusivity, density, and moisture content and assumed specific heat values for mineral material and water.

The instrument was tested on a sample of standard Ottawa Sand for which values of thermal conductivity have been previously published (Woodside and Messmer, 1961). The test was successful, with values of thermal conductivity varying between 1.1 mcal/cm-sec-°C in the dry state to 7.7 mcal/cm-sec-°C in the saturated state, corresponding well to the change from 1.0 to 8.0 mcal/cm-sec-°C in the dry and saturated states,

respectively, determined by Woodside and Messmer (1961). Measurements of thermal diffusivity and calculations of thermal conductivity and thermal inertia are currently being made on samples from the test site. Spectral reflectance measurements of the soil samples are being taken simultaneously using the filter wheel photometer designed by Raines and Lee (1974).

#### Plans for Next Reporting Period

- 1) Completion of measurement of thermal properties of soils.
- 2) Field checking of photo-interpretation and field mapping in volcanic terrain.
- 3) Field measurements of soil temperatures and temperature variations.
- 4) Completion of field hydrogeologic data-gathering, including water-sample collection, spring and stream-discharge measurements, and well pump-tests.

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